# The Optical Gravitational Lensing Experiment. Real Time Data Analysis Systems in the OGLE-III Survey.[1]

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ABSTRACT

We describe three real time data analysis systems implemented during the third phase of the OGLE survey (OGLE-III). The EWS system is designed to detect on-going microlensing events. The EEWS system monitors the microlensing phenomena for anomalies from the single mass microlensing. The NOOS system detects transient objects in the OGLE-III fields (SNe, microlensing events, variable stars) that normally are below the detection threshold. Information on objects detected by each of these systems is distributed to the astronomical community for follow up observations. Also a short description of the OGLE-III hardware and photometric data pipeline is presented.

## 1 Introduction

In June 2001, after the second major hardware upgrade, the Optical Gravitational Lensing Experiment entered its third phase, OGLE-III, and with the data flow of about 3.5 TB/year became a "terabyte" survey. With more than 200 millions of stars observed regularly once every 1–3 nights it became crucial to perform the photometric reductions in real time to avoid saturation by the huge incoming data stream. While the initial reductions of the OGLE-III images were performed in real time from the very beginning, the full on-line photometric data pipeline was implemented one year later for the Galactic bulge fields when sufficient number of good quality frames were collected for each field. Gradually, all the remaining OGLE-III fields were included for on-line photometric reductions and presently all images are reduced within several minutes after the frame has been collected.

From the point of view of the scientific output of a sky survey it is also very crucial to implement systems that can analyze the photometry of the observed fields in real time. Many objects undergo large brightness variations in different time scales and detection of such cases, potentially very interesting, in early phases can be very important for good sampling or follow up observations.

One of such systems, the Early Warning System (EWS) for detection of ongoing microlensing events was designed and installed in 1994 during the OGLE-I phase, as the first system of such type in any microlensing survey. Later similar

[1]Based on observations obtained with the 1.3 m Warsaw telescope at the Las Campanas Observatory of the Carnegie Institution of Washington.

capabilities were implemented by the MACHO group (Alcock *et al.* 1997), in very limited range by the EROS group (Afonso *et al.* 2003) and since 2000 by the MOA Collaboration (Bond *et al.* 2001). The EWS system operated successfully during OGLE-II providing about 40–80 microlensing detections per year.

The modified EWS system was reinstalled for OGLE-III in May 2002 and operated successfully in 2002 and 2003 Galactic bulge observing seasons. Two other real time data analysis systems were also developed and implemented in the past months: EEWS – a system of detection of anomalies in microlensing events and NOOS – a system of detection of transient objects in the OGLE-III fields. In this paper we present description of all these real time systems and shortly describe the data acquisition system and data photometry pipeline of the OGLE-III survey.

## 2 OGLE-III Data Acquisition System

Replacement of the single chip CCD camera with a new "second" generation instrument was the main feature of the hardware upgrade of OGLE-III. The new CCD camera is an eight chip $8192 \times 8192$ pixel mosaic. Each chip of the mosaic is a SITe ST-002a CCD detector with $2048 \times 4096$ pixels of 15 $\mu$m size. This corresponds to the 0.26 arcsec/pixel scale in the focus of the OGLE telescope, and the full field of view of the mosaic is $35 \times 35$ arcmins.

The chips are mounted in two rows on the molybdenum mounting plate in large cryogenic dewar (ND10) manufactured by IR Laboratories Inc. (Tucson, AZ, USA). They are cooled and held at the temperature of $-95$ C. Part of electronics, namely preamplifiers and bias and clock signal filters are also mounted inside the dewar, very close to the detectors. Only one CCD amplifier is used for reading of each chip. Therefore the following electronics consist of eight identical parallel channels. The liquid nitrogen (LN2) hold time of the dewar (capacity of 6 liters) is about 24 hours.

The signals are directed to and from the dewar electronics *via* two hermetic 100 pin connectors. Two small aluminum boxes mounted very close to these connectors hold small printed circuit boards with clock electronics. These boxes are connected with short high quality cables with the larger "gold" box mounted to the instrument base, containing the main electronics boards. The electronics of each channel consists of two parts: DC chain, providing all bias and clock voltages and signal chain: dual slope integrator with LTC1608 ADC converter for signal digitalization. Each channel (output voltages, ADC converter, gain etc.) is programmable by a microcontroller based on digital signal processor (DSP) TMS320C50. Also clocking pattern can be programmed by this microcontroller. The electronics is adjusted in this manner that in the default mode all CCD chips have similar gain value. The readout noise of chips depends on the chip and is in the range of 6–9 $e^-$. The well depth reaches from 60 000 $e^-$ to 80 000 $e^-$. Table 1 lists the gain and readout noise values for each chip. The default clocking pattern allows reading of the mosaic in about 98 seconds.

Table 1

Gain and readout noise of CCD detectors

| CHIP | GAIN [$e^-$/ADU] | READOUT NOISE [$e^-$] |
|---|---|---|
| 1 | 1.31 | 6.7 |
| 2 | 1.36 | 6.3 |
| 3 | 1.37 | 6.2 |
| 4 | 1.34 | 9.2 |
| 5 | 1.32 | 5.9 |
| 6 | 1.33 | 6.7 |
| 7 | 1.33 | 7.1 |
| 8 | 1.34 | 8.7 |

The microcontroller is identical with that used in OGLE-II (Udalski, Kubiak, Szymański 1997) and includes additional DSP board for reading the output of ADC converter of each channel during the next pixel reading time. The data are then transmitted *via* the TAXI line and PC-PCI board to the PC computer located outside the telescope level. This computer can operate locally, but in the normal observing mode it immediately sends the data received from the microcontroller over the GB Ethernet network to the main data acquisition computer located in the control room a few tens meters outside the telescope building. The data acquisition computer reads the incoming stream of data, assigns the coming pixels to appropriate chips and stores the data on the disk in eight independent FITS files of about 17 MB each. They share the same image number but the extension corresponds to the chip number. The total size of each image (eight files) is about 137 MB.

The remaining hardware components of the system, namely the guider, filter wheel and shutter are identical as during OGLE-II (Udalski, Kubiak, Szymański 1997). Only minor modifications to the shutter and filter wheel were necessary to avoid vignetting.

## 3 OGLE-III Photometric Data Reduction Pipeline

The automatic software designed for on-the-fly flat-fielding of the collected frames continuously monitors output from the data acquisition software waiting for the incoming images and begins the operation when a current image is completely read. Each chip in the image is treated separately. The images are de-biased and flat-fielded by a procedure based on the standard IRAF[2] routines from CCDPROC package. Appropriate bias and flat-field images for each chip from the mosaic are prepared in advance by independent code, also based on

[2]IRAF is distributed by National Optical Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with National Science Foundation.

CCDPROC package. To save hard disk space, flat-fielded and raw images are finally compressed with the RICE algorithm. Once every few days they are dumped to a HP Ultrium tape (about 200 GB of raw data per tape) for storage and transportation to the headquarters.

When the current image is preprocessed, the status of its field is verified and if the image is supposed to be reduced in real time then it is processed by the main OGLE-III photometric data pipeline. The photometry software applies the image subtraction method. It is based on the Woźniak's (2000) implementation of the Difference Image Analysis, DIA, technique (Alard and Lupton 1998, Alard 2000) with many software modifications for better performance and stability.

Similarly to the initial pre-processing, images from each chip are processed independently. Depending on the stellar density of the field an image is divided into thirty two $512 \times 512$, eight $1024 \times 1024$ or two $2048 \times 2048$ pixel subframes. In the first step of reductions the shift between the frame and the reference image (see below) is calculated and the subframes of the current image are extracted and interpolated to the same grid of coordinates as the subframes of the reference image. Then the transformation between the current subframe and reference image subframe is derived and the difference image subframe (current minus reference) is created.

In the next step the difference image of the current subframe is searched for objects that brightened or faded. Next, the positions of these detections are cross-correlated with the positions of stars detected in the reference image and two files containing the known variable stars and "new" variable stars (those whose $X$,$Y$ coordinates do not correlate with known stars) in the current difference image are created. Finally, the photometry of all objects identified earlier in the reference image at the position of their centroids is derived. Photometric measurement consists of the measured PSF flux of the star in the difference image (Woźniak, 2000) added to the PSF flux of this object in the reference image, converted then to the magnitude scale.

When all subframes of the current image are reduced, the individual files for each subframe are combined into three global files of a given frame containing current photometry of all reference image stars, detected variable objects and "new" objects in the current frame. One has to remember that many of the "new" objects are artifacts (traces of non-perfectly removed cosmic-rays, non-perfectly subtracted bright stars etc.).

In the final step the photometric databases are updated. The databases are created and updated with the software similar to that used in previous stages of the OGLE project (Szymański and Udalski 1993) with some minor modifications due to somewhat different data input format. Separate databases are created for each chip in a given field, thus the complete set for a field consists of eight separate databases. Moreover, two kinds of databases are created in each case – the large database contains photometry of all stars detected in the reference image while the second one, much smaller, includes only "new" objects that are detected in the subsequent images. While the number of objects is fixed in the former case it gradually increases in the latter. The databases ensure fast and user friendly access to the complete photometry of all OGLE-III objects.

Before a field can be included in the list of the fields whose photometric reductions are performed in real time, a reference image and appropriate files with magnitudes of stellar objects detected in this image must be constructed. The reference image is constructed by stacking and averaging several single good quality and seeing images. The first image on the list of components of the reference image defines the pixel grid of the reference image. Depending on the stellar density in the field the images are divided into 32, 8 or 2 subframes. This division is then preserved during the reduction procedures. Each subframe is treated independently. Before the reference image of a subframe is constructed the shifts of all images on the list of components of the reference image relative to the first image are calculated and appropriate subframes are extracted. Each subframe is cleaned for cosmic ray hits and all known defects of the detector are masked.

Next, precise transformations between the subframe of the first image and the remaining subframes are derived, the subframe pixels are interpolated to the same pixel grid and the scale factor is derived. If the scale is considerably different than the scale of the first image, *e.g.*, due to poor atmospheric transparency, the subframe is removed. In the next step all subframes from the list are averaged after multiplying by the scale factor and correcting for difference in the background level. Finally, the PSF photometry of the subframe of the reference image is derived using the DoPHOT photometry program (Schechter, Saha and Mateo 1993). The flux values obtained with PSF photometry are converted to the scale of the DIA software based on the linear transformation obtained from several tens of the brightest stars. The procedure is repeated for all subframes of a given field.

The reference image has much deeper magnitude range than the individual images. Therefore the PSF photometry obtained from this image is much more accurate and the list of detected stars is much more complete. In the Galactic bulge fields the reductions are performed on thirty two $512 \times 512$ subframes while in the Magellanic Cloud fields on eight $1024 \times 1024$ or two $2048 \times 2048$ pixel subframes depending on the number of stars in the field. Images of each chip in a given field are divided in the same manner.

## 4 Early Warning System (EWS)

The EWS system of real time detection of microlensing events in progress was implemented in 1994 during the first phase of the OGLE project (Udalski *et al.* 1994) as the first system of such type in microlensing surveys. Later – in 1998 – it was adapted for the OGLE-II data pipeline and operated successfully to the end of OGLE-II (end of 2000). In short, the EWS system compared the current brightness of a star with its mean brightness in the reference observing season and registered all objects that brightened more than a threshold for five consecutive times. The threshold depended on the magnitude of star and was derived as three times of the typical magnitude *rms* of non-variable stars at a given brightness. Then, marked objects were further analyzed and promising candidates for microlensing events (both single mass or binary microlensing)

were alerted.

The EWS system in OGLE-III underwent significant modifications compared to the previous OGLE-I and OGLE-II implementation. New photometric data pipeline of OGLE-III, based on the DIA photometry, required a new algorithm for detection of objects varying in brightness. Also, because of large number of monitored stars, of the order of hundreds of millions, the filtering algorithm had to be efficient enough to filter out unavoidable artifacts. The large number of possible artifacts could make smooth operation of the system difficult or practically impossible.

Similarly to old versions, the OGLE-III EWS system operates on stars that are detected in the reference images. In this manner all detected microlensing events have well established baseline brightness what makes their further analysis simpler and more reliable. Because the stars are detected on the reference frames that are the average of several co-added good seeing individual frames, the stellar detection threshold is much lower than in the individual images making the stellar lists much more complete.

Difference image resulting from subtraction of the current and reference images serves as an indicator of stellar variability in the field. Output files from the photometric data pipeline that contain variable objects detected in the current difference image which were cross-identified with the entries in the list of stars from the reference image, are used by EWS. The appropriate flags are set in the so called variability index created for each field and each chip. The variability index is updated at the same time when the current frame is added to the photometric database and contains easy to search information on the photometric behavior of a given star in the field. The entries for each star in the index contain the total number of points when the star was detected as bright or faint in the difference images and the current number of consecutive measurements when the star was bright (faint). Because detection of objects in the difference images is seeing dependent, the number of consecutive measurements allows for one missing detection before it is set back to zero. To avoid large number of very low variability bright objects an additional constraint on variable stars is imposed, namely the brightening or fading of a star has to be larger than 0.06 mag. This limit effectively works only for the brightest stars. For fainter stars the detection in the difference image provides a natural detection threshold. It is somewhat lower than the detection limit used in the OGLE-I and OGLE-II version of the EWS system.

The variability index provides additional field for masking variable stars and artifacts. Because the fields observed during OGLE-III are seasonal, after each observing season all objects that were detected during that season in the difference images more than once, either brighter or fainter than in the reference image, are flagged. In this manner most of the periodic or long term variable stars and also artifacts (artificial variable objects often close to saturated stars etc.) can be removed from the sample monitored for microlensing events. Separate flagging of the consecutive observing seasons makes the index useful not only for the detection of current variability but also for analyzing the past variability.

To select microlensing event candidates the EWS software scans the variability indices after each observing night. When the number of consecutive observations of a star brighter than the threshold is larger than a preassigned number, currently $N=2$, and the star was non-variable in the reference season(s), the object is marked for further analysis. The light curves of these stars are then inspected visually. The vast majority of marked objects are artifacts resulting, for instance, from contamination of the measurements by nearby bright and severely saturated stars, CCD detector defects, non-perfectly removed cosmic ray hits etc. Also observations at very poor seeing conditions can contaminate photometry (poor image subtraction) leading to artificial detections in some cases. New artifacts can also be masked using additional flag in the variability index.

Selected microlensing event candidates showing the light curves that resemble the light curves of microlensing events are further verified in images. It is checked whether the star indeed increased its brightness. Candidates that passed this step are considered as possible microlensing events. The automatic software prepares the photometry dataset, finding charts, plots of the light curve, appropriate files for the ftp archive, WWW page for each event and the EWS announcement. When all candidates from a night are processed the announcement is e-mailed to the EWS mailing list subscribers.

The performance of the EWS system strongly depends on the quality of filtering. The OGLE-III EWS system became operational in the beginning of May 2002 for the 2002 Galactic bulge season. Unfortunately, the number of observations collected for the Galactic bulge in the previous (2001) season was relatively small (of the order of 10–20), because less than half of the observing period was covered. Therefore during the 2002 season the filtering of variable stars and artifacts was not tight enough and large number of false objects were usually selected for visual inspection after each night. Due to large number intensive masking of the marked variable stars and artifacts was necessary, practically after each night, to ensure reasonable operation of the system. A side effect of such a mode of operation were possible errors in identification of real microlensing effects. The best example is the spectacular high magnification microlensing event MOA 2002-BLG-33 alerted by the MOA group on 2002, June 18 (Abe *et al.* 2003). The same event (catalog name BLG205.1 121022) was triggered by the EWS system at very early phases of lensing on 2002, May 12. The candidate was overlooked among hundreds of artifacts, then masked and in this manner remained undetected by the EWS system. Another drawback of so early operation of the system was relatively large contamination by variable stars of microlensing candidates announced in the 2002 season, reaching 11%. For instance, short baselines did not allow to exclude cataclysmic variables – a few evident dwarf novae were alerted as possible microlensing candidates: 2002-BLG-077, 2002-BLG-090, 2002-BLG-119, 2002-BLG-129. Also many microlensing events were announced relatively late – near or after maximum – and therefore they were not suitable for follow up observations by other microlensing groups. Nevertheless, the overall operation of the system in 2002 was successful – the total number of detected microlensing events (about 350) was comparable with the

total number of events discovered during the MACHO or OGLE-II surveys.

The operation of the EWS system was suspended at the end of the 2002 Galactic bulge season in November 2002. It was resumed at the beginning of May 2003 for the 2003 Galactic bulge season. Due to much longer time span available for filtering out variable stars and artifacts (2001 and 2002 seasons) operation of EWS during the 2003 bulge season was very smooth as the filtering was much more effective than in 2002 season. Typically the number of objects for visual inspection after each night was about 100–300 for about 100 million photometric measurements. With so small number of triggered objects flagging the artifacts was not necessary and therefore the chance of missing an event was considerably smaller than during the 2002 season. Contamination of alerted candidates by variable stars was also smaller than in the 2002 season, although a few dwarf novae again mimicked binary microlensing events: 2003-BLG-034, 2003-BLG-271. The total number of alerted microlensing event candidates in the 2003 season reached about 460.

One should remember that even with perfect filtering the EWS system may miss some microlensing events. The system requires now three detections of the brightening of a star to mark it as a candidate. The typical sampling of the Galactic bulge fields in the middle of the season is on average once per 1.5–2 nights and less frequent at the beginning or the end of the season. Therefore very short time scale events might be missed or discovered well after maximum, in particular when the regular sampling of the fields is affected by longer periods of bad weather, passage of the Moon close to the bulge fields (observations are typically suspended for 2–3 nights) or other reasons.

The EWS system will operate in similar mode with some minor adjustments during the following Galactic bulge seasons. A small number of new fields will be added at the beginning of the 2004 season while some fields with no or small number of microlensing detections will not be monitored anymore. Also starting from the beginning of 2004 all OGLE-III Magellanic Cloud fields will be monitored by the EWS system. Altogether the EWS system monitors more than 200 million stars: 33 and 170 millions in the Magellanic Clouds and the Galactic bulge, respectively.

Information on the current status of the EWS system microlensing candidates can be found from the following addresses:

- OGLE main page:

  *http://ogle.astrouw.edu.pl/*
  *http://bulge.princeton.edu/˜ogle*
- EWS system main page:

  *http://ogle.astrouw.edu.pl/ogle3/ews/ews.html*
- EWS system ftp address:

  *ftp://ftp.astrouw.edu.pl/ogle/ogle3/ews*

One can subscribe to the EWS mailing list from the main EWS page.

## 5 Early Early Warning System (EEWS)

Observations of a disturbance in the standard light curve of a single mass microlensing event can provide additional and very important information on the lensing system. While some of the disturbances occur in long time scales (*e.g.*, a parallax effect) and can be easily detected with regular survey mode sampling of the observed fields (provided the photometric accuracy is good enough) some other may have time scale of hours and can be easily overlooked or poorly sampled with regular observing pattern of the OGLE-III survey. Of particular interest are disturbances induced by planetary companions of lensing stars or first caustic crossing in binary microlensing. In the latter case the moment of the first caustic crossing is highly unpredictable contrary to the second caustic crossing which time can be estimated from earlier observations. The passage through the caustics lasts typically a few hours so it is essential to observe the event every few minutes. Good coverage of both caustic crossings is very important for unambiguous modeling of a binary event. In the case of disturbances caused by planetary companions of the lensing star its time scale can also be of the order of hours and again frequent observations of the event are crucial for correct interpretation of the event. The best example here is the microlensing event 2002-BLG-055 where a single data point deviation from single mass microlensing was observed on the falling part of the light curve. Modeling of the light curve suggested possible planetary signal (Jaroszyński and Paczyński 2002) but due to scarce coverage of the light curve at the moment of the deviation other interpretations of the event cannot be ruled out.

The Early Early Warning System (EEWS) is another OGLE-III system of data analysis working in real time aiming at the detection of deviations from the regular single mass microlensing light curve profile. The main goal of the system is to provide the OGLE observer fast information on the current behavior of already discovered microlensing events and enabling the observer fast response, *i.e.*, changing the regular survey mode to follow-up mode of frequent observations of a particular event.

The EEWS system works in the following way. When a new frame is collected and then flat-fielded by the automatic procedure (Section 3), the EEWS daemon selects the microlensing events from this field using the list of already known microlensing events in the OGLE-III fields. The list includes all well observed events with light curves of good enough quality from all OGLE-III seasons. The list is regularly updated when new events are discovered by the EWS system. Presently (after 2002 and 2003 observing seasons) the list comprises about 470 objects.

For each lens from the field independent reduction procedures are performed on the subframe of the current frame where the lens is located in. A separate dedicated for the EEWS system CPU is used for photometric reduction. The reduction procedure is identical with that of the standard OGLE-III photometric pipeline, but due to small size of the subframe the reduction takes just a few seconds. In the next observing seasons this step will not be necessary, because after a recent upgrade the current CPU power available in OGLE-III is large

enough that standard pipeline reduction of a frame is finished within a few minutes after it has been collected.

When the current magnitude of a lens is derived it is compared with the magnitude predicted by the single mass model light curve fitted to the previous observations. If the difference is larger than three times the error of the observation or a preassigned threshold (0.15 mag), whichever larger, the EEWS system prepares the appropriate plots and data files and e-mails a "RED ALERT" to the observer. After visual inspection of the current frame, difference frame, the light curve of the event etc. the observer undertakes further action if the alert is promising: it switches the observing program from the survey mode to the follow-up mode. The deviating lens is observed more frequently with the sampling appropriate to changes of its brightness. Typically, the current light curve and photometry is available to the observer after 1–4 minutes after observation.

The EEWS system was implemented during the 2003 Galactic bulge season at the end of May 2003. Soon after that the first important alert was made, namely the EEWS system alerted fast brightening of the microlensing event 2003-BLG-170. The brightening turned out to be a crossing of the first caustic in binary microlensing. Due to the "RED ALERT" from the EEWS the caustic crossing, impossible to predict in advance, was very well sampled. Another examples of spectacular events alerted by the EEWS system include 2003-BLG-238 (deviation due to finite size of the source star) and 2003-BLG-267 microlenses (again crossing of the first caustic in binary microlensing). Fig. 1 presents the light curve of OGLE 2003-BLG-267.

Operation of the EEWS system during the 2003 Galactic bulge season proved that it works effectively and is very important tool for increasing flexibility of the OGLE-III survey to the events requiring fast time response. One has, however, to remember that the sensitivity of the system is limited at early phases of microlensing events, *i.e.*, before the maximum of light. At these stages the microlensing fit to the observations is usually poorly constrained, in particular for fainter stars or when the gaps between observations are larger due to, for instance, bad weather. Therefore, it is not always possible to recognize and correctly interpret a new deviating observation. Very often the old observations combined with a new deviating one provide a microlensing fit of similar quality to the old one (with different parameters), especially when the amplitude of the deviation is small. In this manner it is easy to overlook an interesting deviation. The situation is much better after the maximum of microlensing event. Then, the fit to the large part of normally behaving single point microlensing is so well constrained that even a small magnitude deviation can be easily recognized. For example, were the EEWS system implemented in 2002 observing season, the 2002-BLG-055 lens deviation from single mass microlensing would certainly be detected and alerted and more observations of this possible planetary disturbance would be collected at crucial moments.

The EEWS system will be used by OGLE-III during the next observing seasons. Similarly to the 2003 season we plan to distribute EEWS alerts *via* our EWS network informing the microlensing follow-up groups about very interesting events requiring instantaneous observing response.

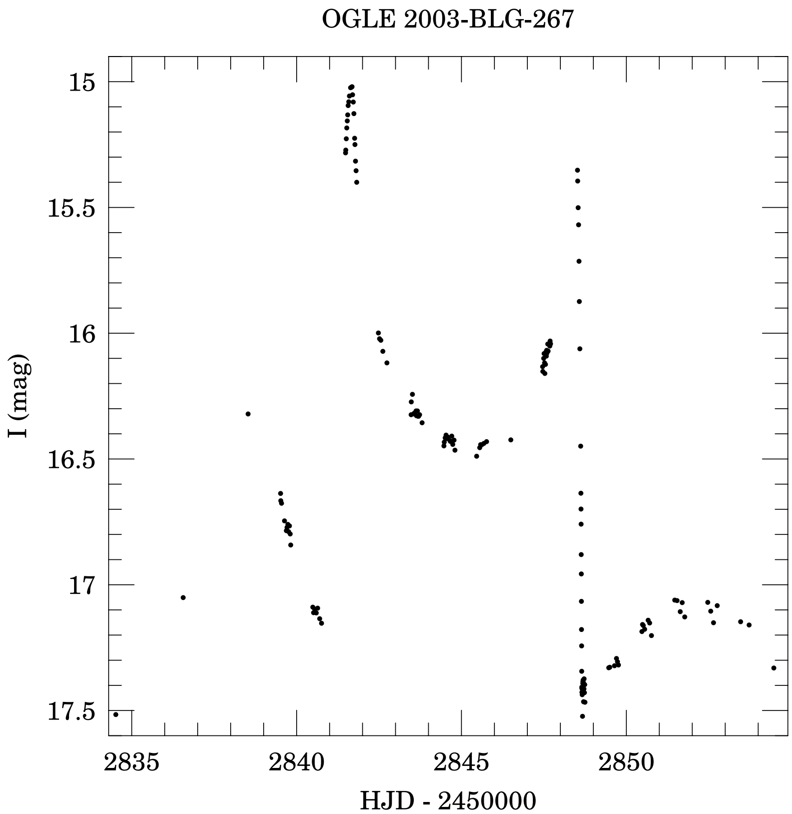


Fig. 1. Light curve of OGLE 2003-BLG-267 binary microlensing event. The event was alerted by the EEWS system on HJD=2839.5 enabling good sampling of crucial phases of the event.

# 6 New Objects in the OGLE Sky (NOOS)

The EWS and EEWS systems operate on stars previously detected in reference images of the OGLE-III fields. Because the reference image is a co-added image of several best individual images its range is deeper than that of regular frames. However, if objects that are fainter than the detection threshold of our reference images increase their brightness they can be temporarily seen in the OGLE frames. Such transient objects can potentially be very interesting. Therefore another real time data analysis software was designed and implemented in OGLE-III: the New Objects in the OGLE Sky (NOOS) system.

The main goal of the NOOS system is the detection of transient objects in the OGLE-III fields. After each observing night, when the OGLE databases are updated, the NOOS scans the databases of "new" objects looking for entries that have more than selected number of detections (currently $N=2$). Such objects are marked for further analysis. Next, the automatic software prepares the finding charts for each candidate – a part of the reference image of a given field with position of the analyzed transient marked. These finding charts are

visually inspected for objects whose positions do not coincide with nearby bright (often saturated) stars, defects on the detector etc. For promising candidates the most recent frames are then inspected to verify whether the detection is real. The remaining objects are masked so they do not contaminate further NOOS operation.

If the candidate is accepted then its photometry is derived by re-running the reduction procedures (identical to the OGLE standard photometric pipeline) and measuring the flux of the transient at its "bright" position. Fifteen images prior the detection are typically measured. Next, the light curve plots, finding charts, as well as the WWW page and ftp archive files for the object are prepared. An alert notifying subscribers about the discovery is also prepared and distributed *via* the OGLE NOOS alert mailing list.

The NOOS system was implemented in the middle of November 2003. The Magellanic Cloud fields were the first targets, altogether about 53 square degrees around both Clouds. During the first month of operation more than ten new transient objects were detected in these fields. Additional ten were found in the earlier data – collected from the beginning of the 2003/2004 season (September 2003). The typical detection threshold of a transient is $I\approx 19.8$ mag. The typical lag of detection is about 6–10 days after a transient becomes brighter than the detection threshold. Good sampling of the observed fields (once every 2–4 nights) ensures well covered light curves of the transient objects.

The sample of the transients detected so far indicates that the full variety of objects may belong to this class: SNe, high magnification microlensing events of faint stars, cataclysmic variables or other variable stars of large amplitude. Sometimes the light curve may provide a clue to classification. For instance, several transient objects detected by the NOOS system are certainly SNe, usually detected by NOOS before maximum of light (*e.g.*, 2003-NOOS-005, 2003-NOOS-006, 2003-NOOS-012, 2003-NOOS-016, 2003-NOOS-020). However, in many cases follow up observations are needed, in particular spectroscopy. Therefore, we encourage observers to follow up the OGLE–NOOS variables. Anything that suddenly brightens is potentially very interesting and worth observing. As an example of transient objects the light curve of a SN – 2003-NOOS-005 – is shown in Fig. 2, and a transient – 2003-NOOS-011 – in Fig. 3.

The NOOS system will also cover the Galactic bulge fields starting from the 2004 Galactic bulge season. It is expected that the vast majority of transients from this region will be high magnification microlensing events of faint Galactic bulge stars.

Information about the transients detected by the NOOS system can be found from the following addresses:

- OGLE main page:

*http://ogle.astrouw.edu.pl/*
*http://bulge.princeton.edu/˜ogle*

- NOOS system main page:

*http://ogle.astrouw.edu.pl/ogle3/ews/NOOS/noos.html*

- NOOS system ftp address:

*ftp://ftp.astrouw.edu.pl/ogle/ogle3/ews/NOOS/*

Astronomers interested in receiving e-mail notification on new discoveries may subscribe to the NOOS mailing list from the main page of the NOOS system.

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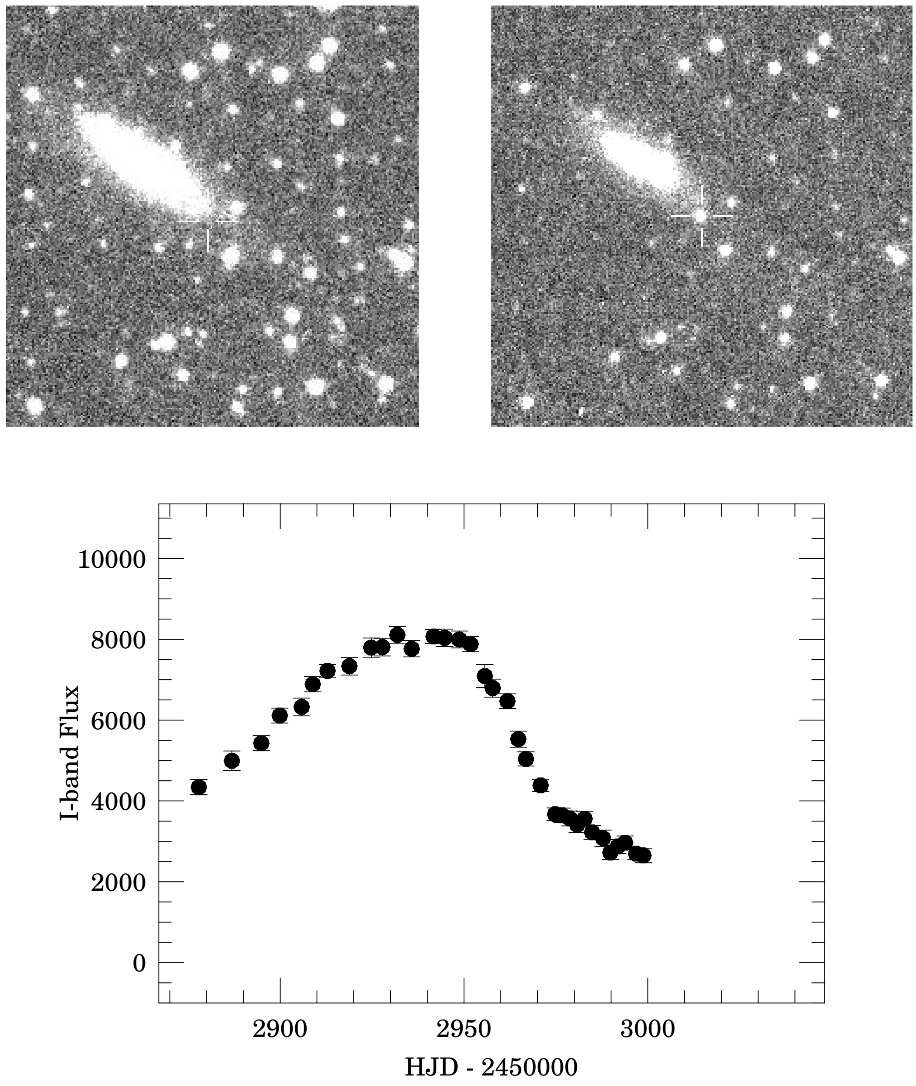


Fig. 2. Field and light curve of the SN OGLE 2003-NOOS-005.

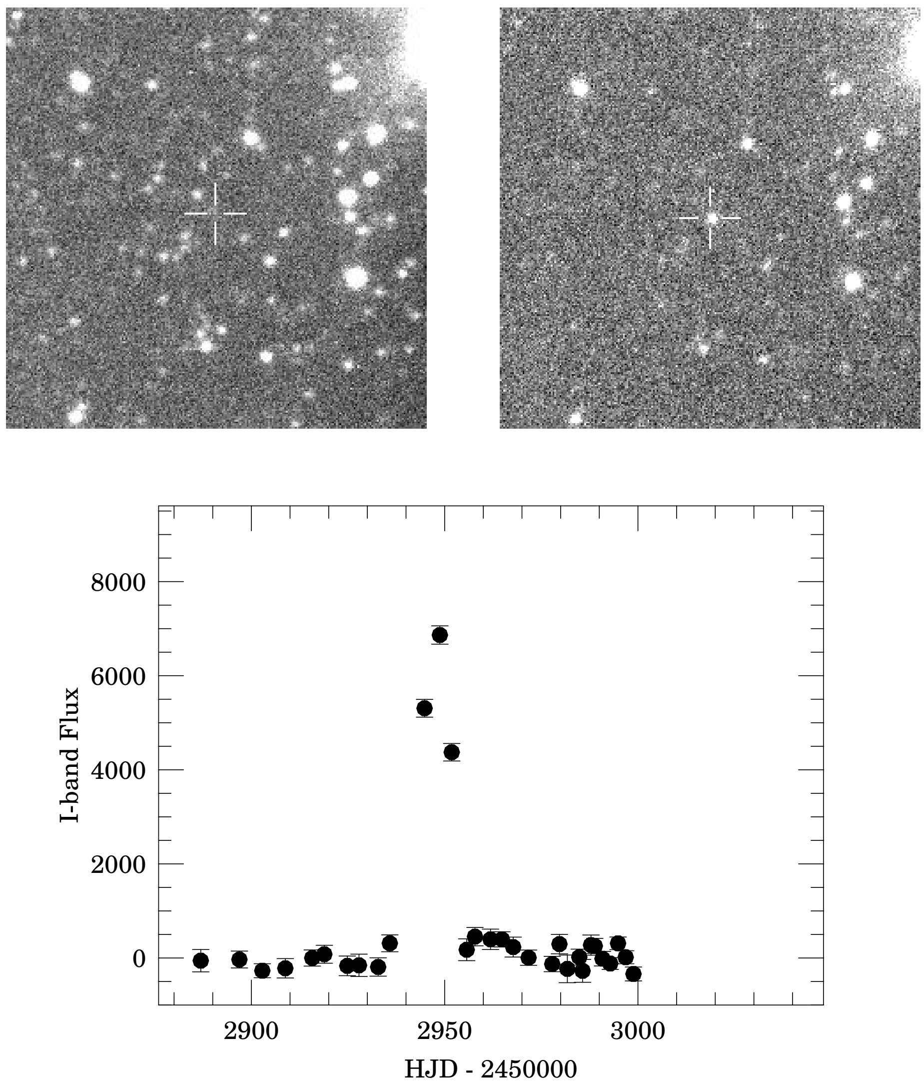


Fig. 3. Field and light curve of the transient OGLE 2003-NOOS-011.